Battlefield Augmented Reality System (BARS)

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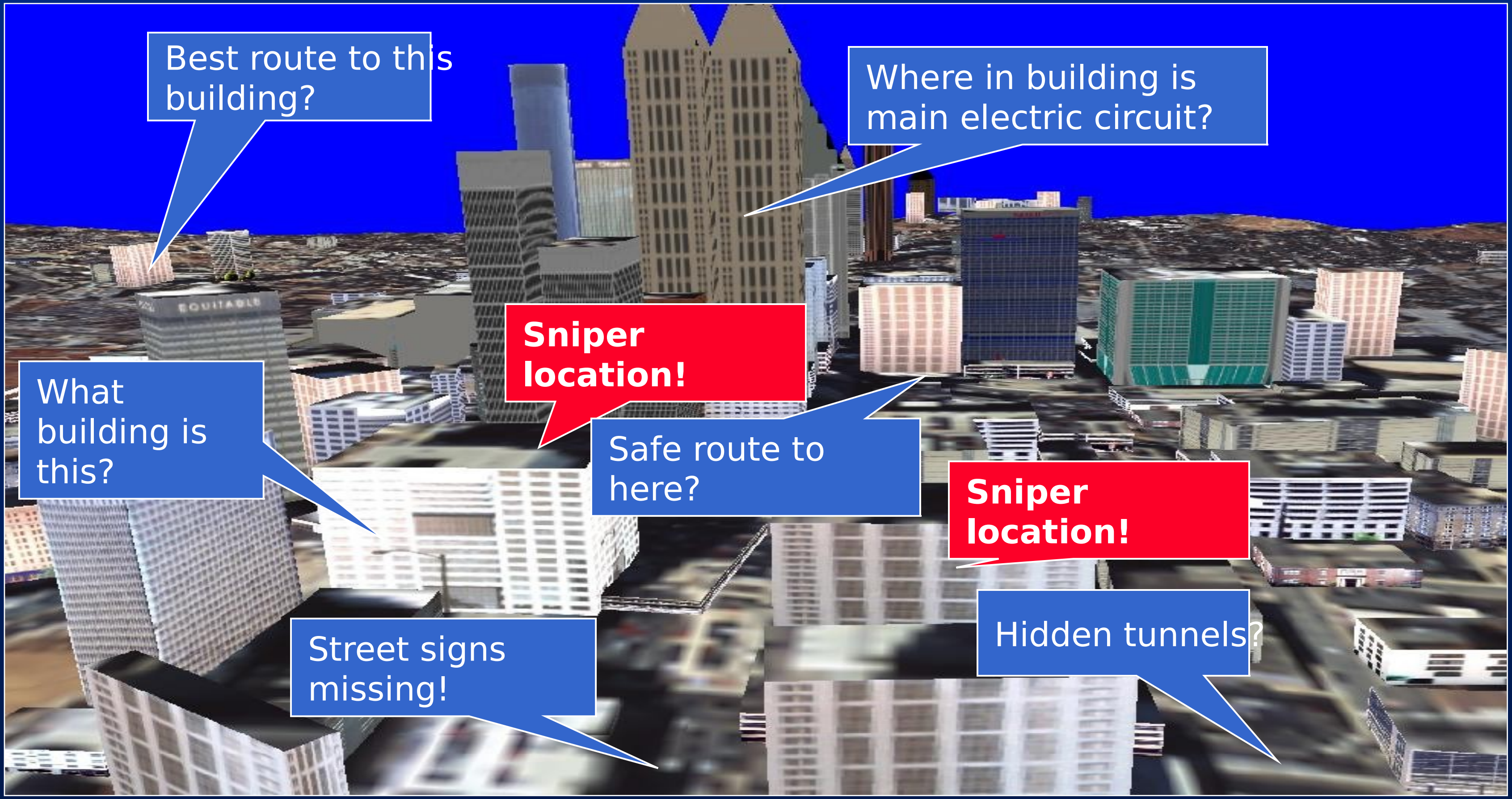
www.ait.nrl.navy.mil/vrlab

Click on NATO Conference

Operational Issue

- Changing nature of military operations
  - Peacekeeping
  - Surgical strikes
- Operating in the *Urban Canyon*
  - Avoid risks hidden in infrastructure (snipers, mines, ...)
  - Maintain knowledge of position, routes, ...
  - Coordinate with team members
  - Minimize civilian casualties
- Examples
  - Grenada, Panama, Somalia, Haiti, Bosnia, and Los Angeles

Improved Operations in the Urban Environment



Reconstruction of Atlanta (Courtesy GVU Center, Georgia Tech)

Military Requirement

"...we must explore new technologies that will facilitate the conduct of maneuver warfare in future MOUT. Advanced sensing, locating, and data display systems can help the Marines to leverage information in ways which will reduce some of the masking effects of built-up terrain."

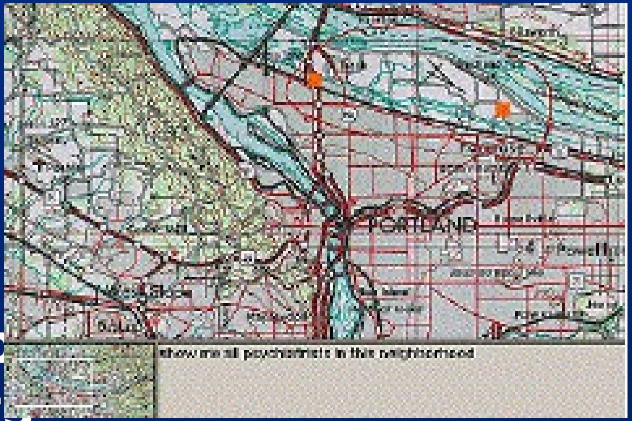
– Future Military Operations on Urbanized Terrain, United States Marine Corps Warfighting Concepts for the 21st Century, Concepts Division, MCCDC, 1999

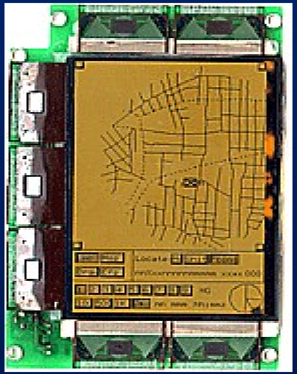
"Units moving in or between zones must be able to navigate effectively, and to coordinate their activities with units in other zones, as well as with units moving outside the city. This navigation and coordination capability must be resident at the very-small-unit level, perhaps even with the individual Marine."

– Concepts Division, Marine Corps Combat Development Command, "A Concept for Future Military Operations on Urbanized Terrain," 1997

Shortcomings of Existing Methods

- Radioed instructions are hard
  - to visualize
  - to integrate into tactical pictu
- Paper / electronic maps
  - force user to correlate map with environment, even if map automatically updates / orients
  - do not represent 3D nature of urban infrastructure
- Handheld displays
  - divert attention from surrounding environment
- Monocular displays
  - obscure environment





Personal Digital Assistant (PDA)

Wearables Become Wearable

- **Wearable computer; Tracked, see-through head-worn display; Interaction devices**

ONR 6.1 testbed wearable: **tracked see-through display**

Commercial wearable: **untracked opaque display**

MicroOptical Corp.: **eyeglass display**

Approach

- Develop a ***wearable***, ***see-through***, ***augmented reality*** system that provides warfighting information to ***collaborating***, ***networked*** personnel in the battlefield

- Develop a ***3D, Interactive*** Command Environment (3DICE) that provides warfighting information to ***collaborating, networked*** personnel in the battlefield

Our focus is on algorithms, software architecture, user interface, and evaluation — <u>not</u> hardware. COTS hardware will be used

Linking the Dismounted Warrior and the Command Center

3DICE

Tactical Picture

Recon

Dismounted Warriors

Environment / Tactical Picture

Recon

Environment

Battlefield Network Information System

Mobile Augmented Reality (AR)

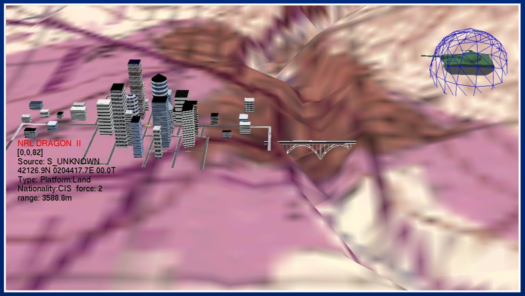
User position and orientation tracked

Graphics overlaid directly in real world

- **Advantages**
  - Mobile personnel have *hands-free* access to information
  - Information overlaid on real world
  - Eliminate cognitive time and effort switching between real world and information display

3D Interactive Command Center (3DICE)

Responsive workbench provides “god’s eye view”



GROTTO/CAVE

- **Advantages**
  - Accurate representation of 3D terrain
  - Freedom to change position and vantage point from “god’s eye view” to individual dismounted warrior in the field

CNN Headline News

Research Goals for BARS

- New techniques for mapping spatial information between 3D virtual environment and AR display domains
- Mobile AR tracking and registration
  - Novel estimation and feature mapping algorithms
  - Performance and accuracy requirements
- New AR / VR multimodal interaction techniques
- First exploration of interplay between VR-generated synthetic combatants and AR
- Evaluation of BARS
  - Quantification of user's situational awareness
  - Ranking of interaction methods
    - Metrics: topographic knowledge, scenario completion time, error count, etc.
- Software architecture for integrated AR / VR system
- Prototype BARS and demonstrations

Research Topics

- High Precision Registration
  - Hybrid tracking
  - In-the-field calibration
- User Interface Design
  - Design of graphical representations
  - Environment management to avoid information overload
  - Perceptual / multi-modal interaction
- Environment Modeling
  - Tailoring for information presentation
  - Persistent database representation
  - Physical modeling of urban environments
- Software Architecture
  - Real-time multi-user collaboration
  - High performance on wearable computers

Tracking

- **Objective**
  - Measure position and orientation of user

- **Approach**
  - Analyze accurate needs
    - Static and dynamic accuracy
  - Implement Closed-Loop Tracking System
    - Switched multiple data sources
    - Feature recognition and matching
    - Multi-sensor data fusion

Open-Loop Tracking System
Each device works independently

Calibration

- **Objective**
  - Precisely align graphics with real world
- **Approach**
  - Model optical characteristics of display
    - Optical studies to determine field-of-view, distortion
  - Develop real-time, interactive, in-field calibration framework

Display which is only optically calibrated. Field of view is correct but the orientation of the display on the user's head is not correctly compensated for

Graphical Representation

- **Objective**
  - Develop different types of display graphics (e.g., arrows, labels, etc.)
- **Approach**
  - Develop taxonomy of different display types
  - Implement most likely candidates
  - Evaluate

Graphic from NRL Dragon System showing diversity of graphical symbology

Environment Management

- **Objective**
  - Organize graphical display to optimize relevant information and minimize overload

- **Approach**
  - Filter data to determine what is most important
  - Manage environment to optimize presentation style

Dense environments can lead to clutter and confusion

Multi-modal Interaction Methods

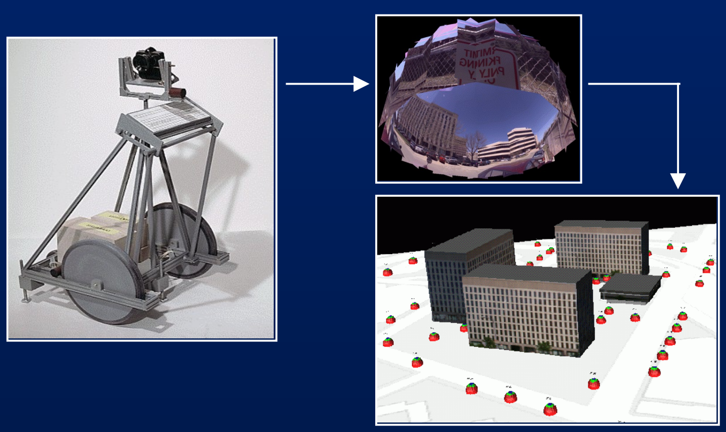
- **Objective**
  - Enter reports and make queries
- **Approach**
  - Extend 6.1 research in multimodal methods (speech + gesture) to mobile urban warfare domain
  - Evaluate different interaction methods for “best” solution

OGI’s Quickset & NRL’s IVRS software are used to lay 3D digital ink on a Workbench using integrated voice and gesture

Physical Modeling

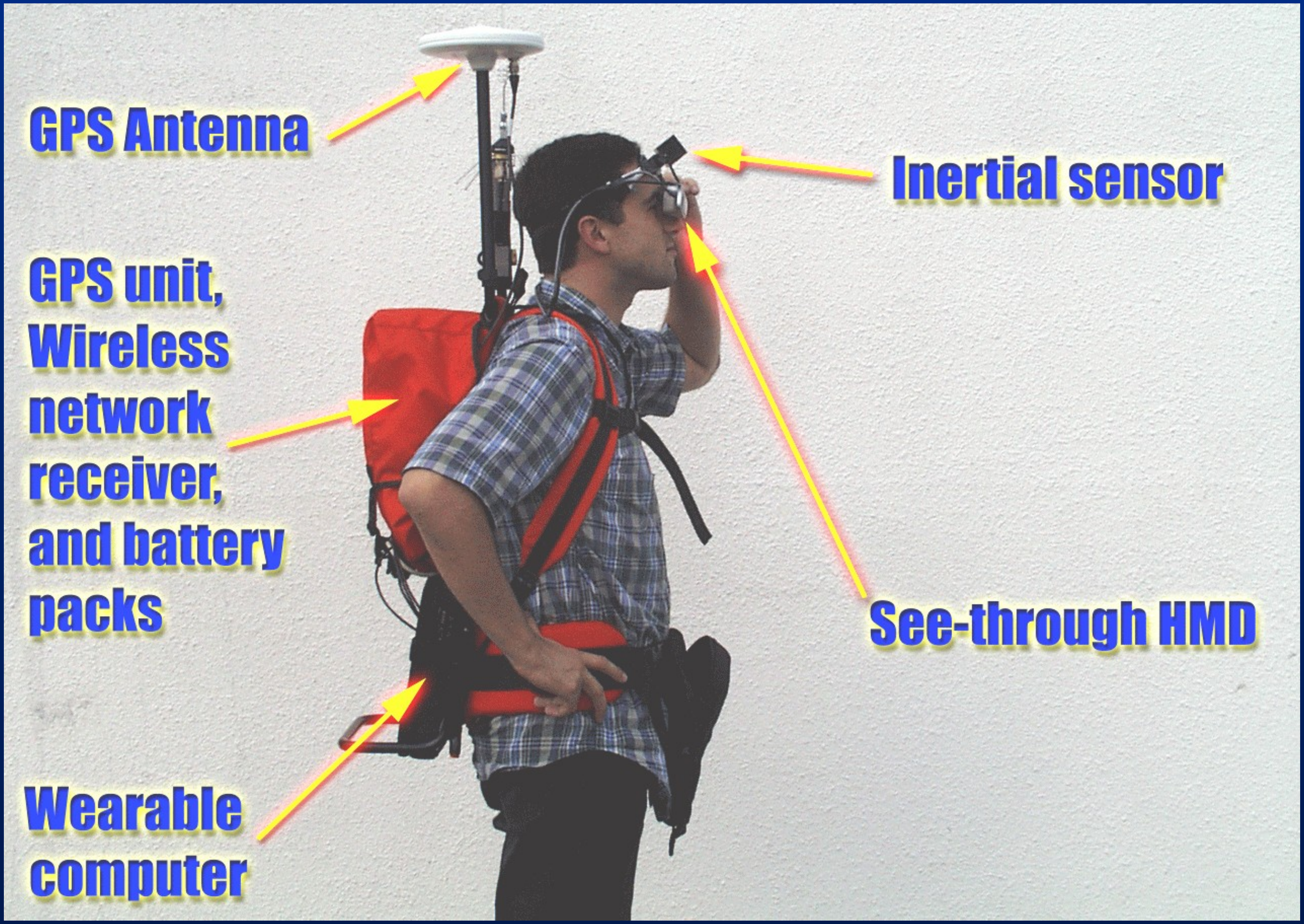
- **Objective**
  - Construct accurate, detailed 3D models of environment
- **Approach**
  - Leverage off ONR-funded (and other) programs
  - Develop accurate hand measured test suite
  - Combine with mobile AR system

UC Berkeley's FAÇADE system uses pictures and manual registration



MIT's system reconstructs scenes from thousands of images collected by a mobile robot

Phase I System

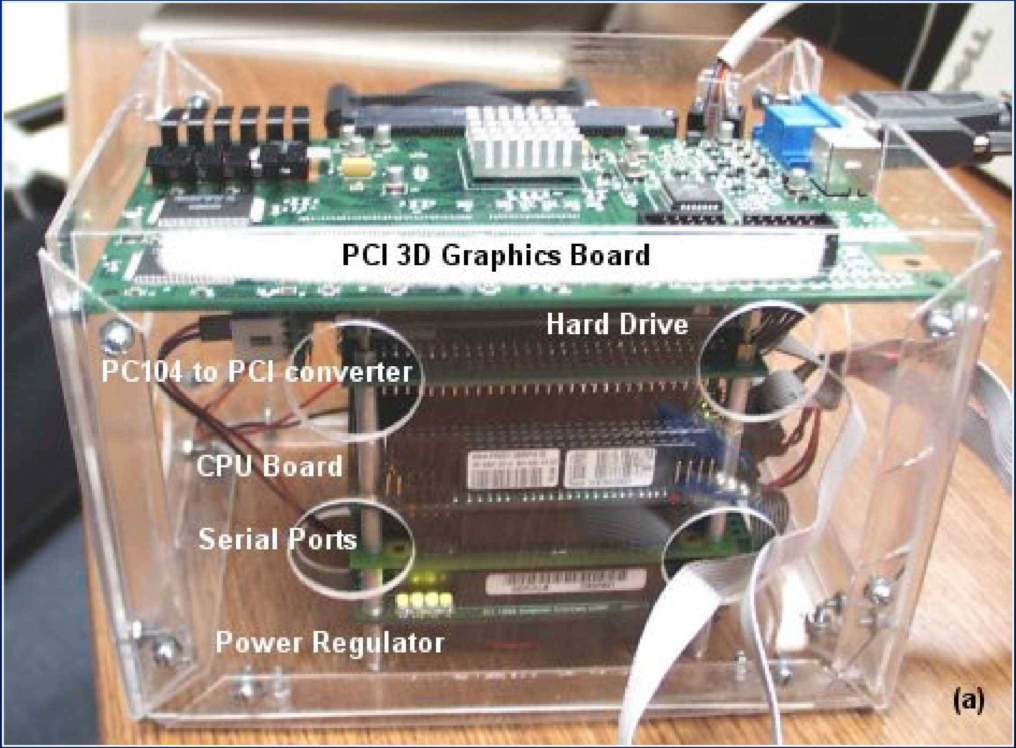


Developed purely from COTS products

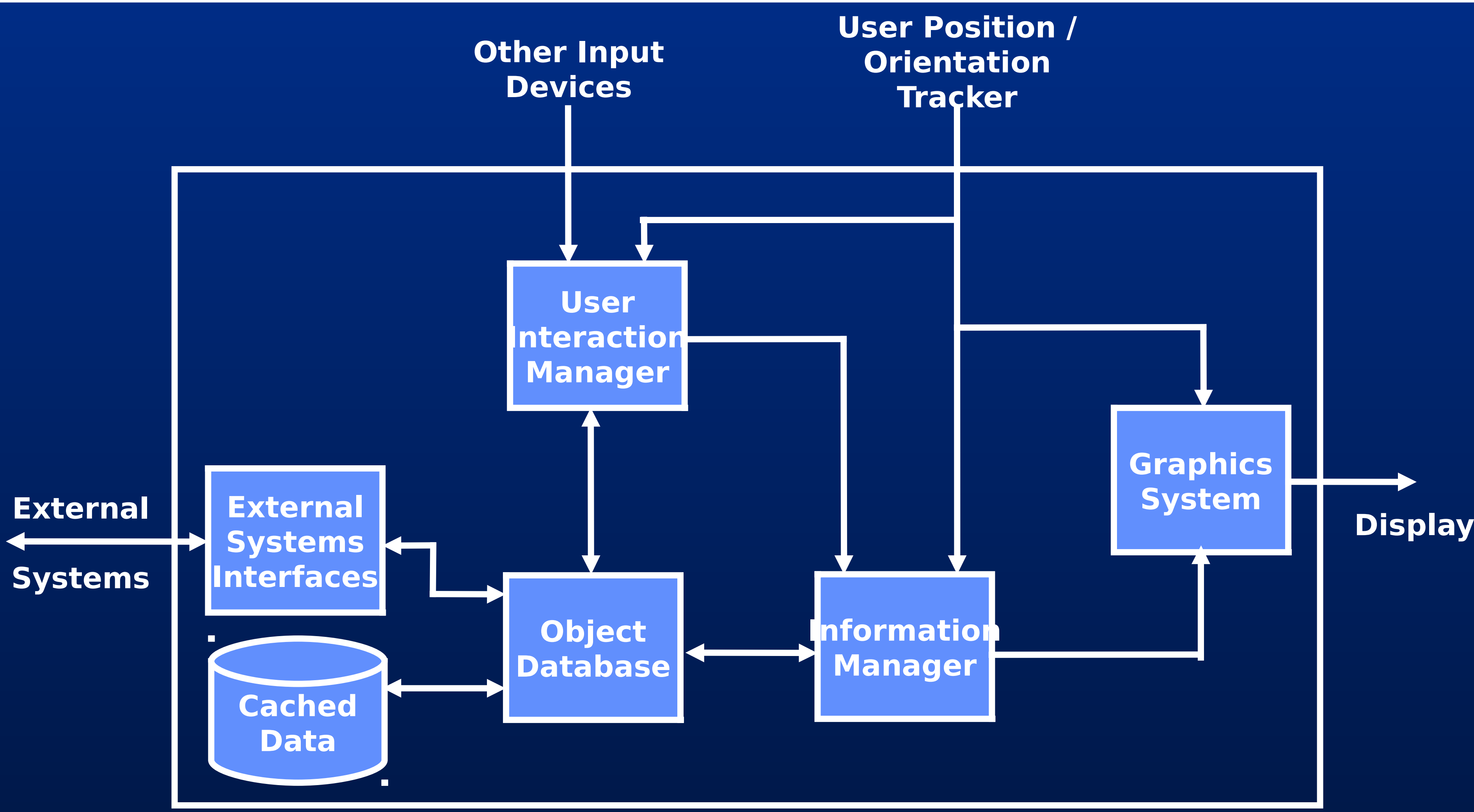
3D Graphics Hardware

- **PC104-based computer**
  - **Pentium MMX 266 MHz**
  - **64MB memory**
  - **Windows NT**

- **Hardware 3D stereo graphics accelerator**
  - **Fire GL 1000Pro**



Mobile System Architecture



Direct Environment Information

Wireframe annotation of buildings highlighting critical features

Route between points of interest (denoted by flags)

- **Annotation of the environment**
  - Building names, sizes and physical relationships
  - Detailed environmental information (windows, doors)
  - Routes, points of interest

Other Types of Information

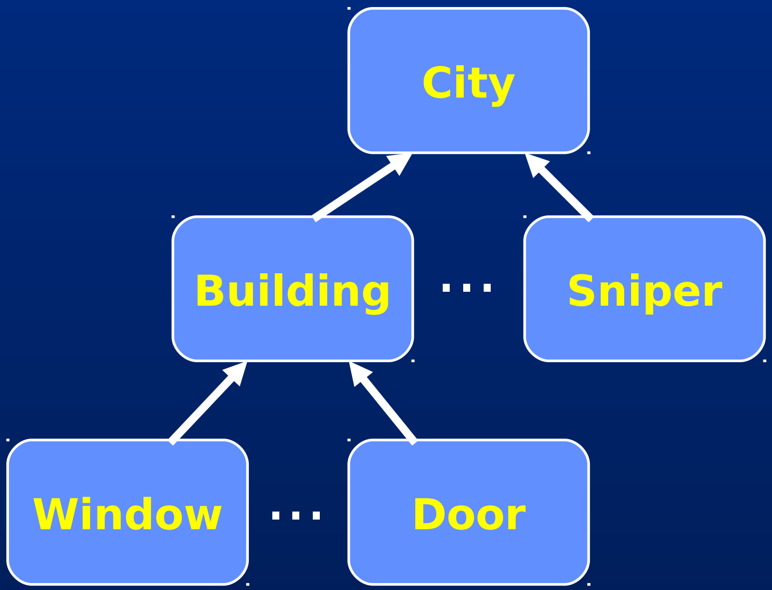
Site of former building

Data about buildings can be requested

- Information displays
  - Detailed information about objects and environment
  - Virtual environment objects

Environment Modeling

- Data structure
  - All environment components are "first class" objects
  - Arranged using hierarchical containment
  - *Region of influence* encodes volume affected
  - *Importance vector* encodes importance with respect to multiple *objectives*

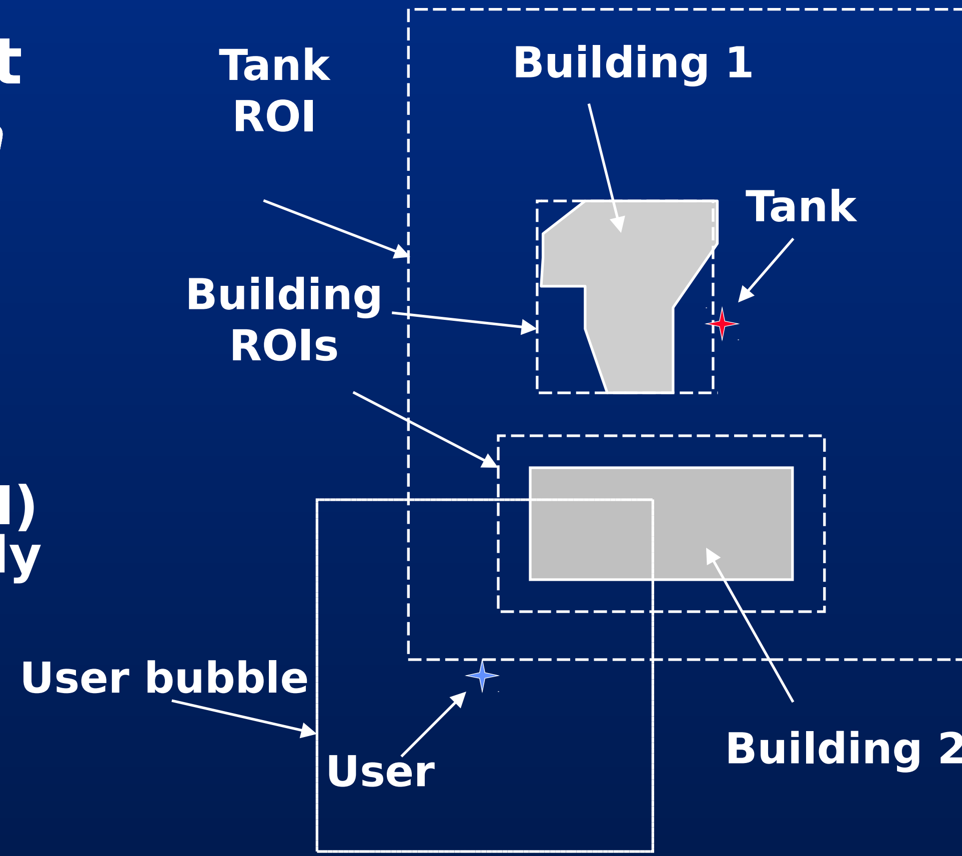


Sample object hierarchy.
Each box is an object in the database.

Information Filtering

- **Subset of environment chosen by *information filter***
  - **User is surrounded by "bubble"**
  - **All other objects have a Region of Influence (ROI)**
  - **ROI is calculated on the fly as a function of object properties and current user goals**
  - **All objects whose ROI intersects with bubble are candidates to be shown**

Subset of environment chosen by information filter
User is surrounded by "bubble"
All other objects have a Region of Influence (ROI)
ROI is calculated on the fly as a function of object properties and current user goals

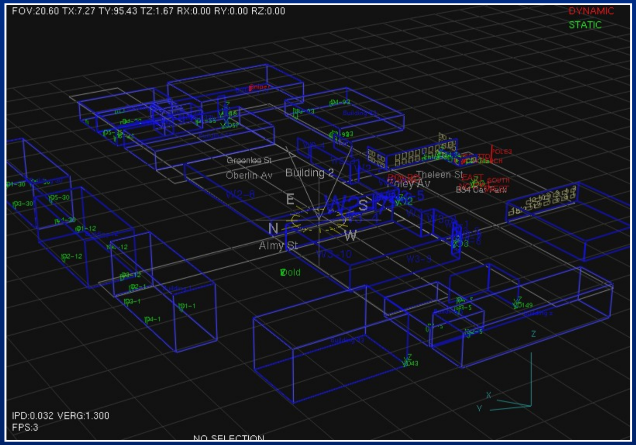


A Filtering Example

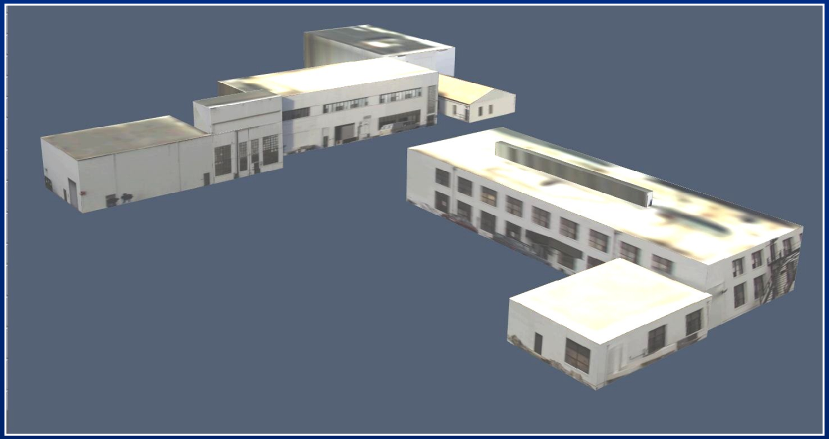
Original, cluttered view

Filter chooses only the most relevant features

Environment Modeling



Geometric model of NRL

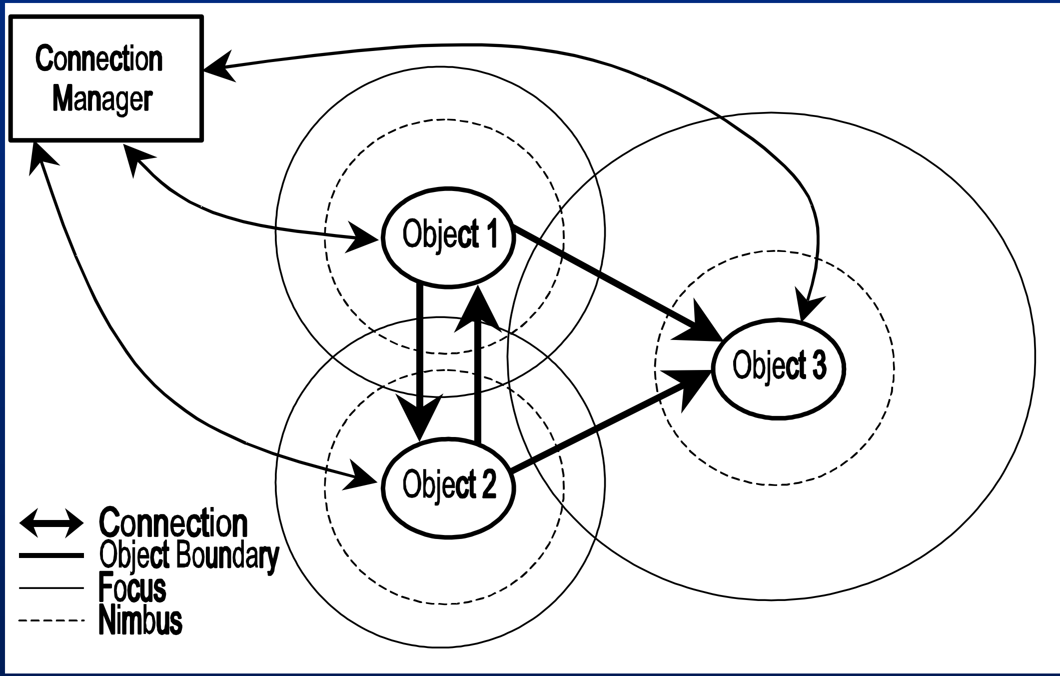


Textured model of NRL

- **Detailed models of NRL:**
  - **“Lightweight” photogrammetric methods (Berkeley)**
  - **Detailed measurements/site plans**
- **Each model has >80 objects including buildings, doors, windows, points of interest**

Aura-Based Data Distribution

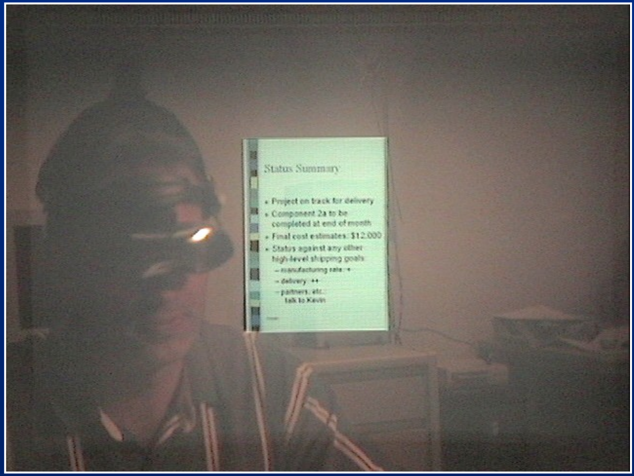
- All objects have nimbus
- Some objects have focus
- If focus of A overlaps nimbus of B, A receives replicated copy of B

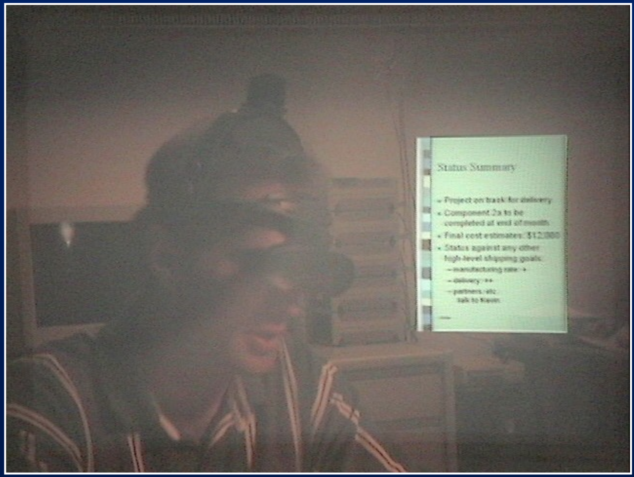


Objects 1 and 2 contain copies of one another. Object 3 is a "stealth" viewer - its focus intersects the nimbuses of Objects 1 and 2 and so it receives copies of these objects. However, neither Object 1 nor Object 2 creates or receives updates of Object 3

Environment Management

- **Initial implementation of environment management**
  - **Position of object (other user) tracked**
  - **Information (menu) moved to avoid obstruction**





University / Industry Collaborations

- Columbia Univ. (Feiner) funded by ONR to participate in BARS
- Coordinated with other ONR-funded AR efforts:
  - USC (Neumann) research for fine-scale registration
  - GeorgiaTech (MacIntyre) research for semantical entity representation
  - UW (Furness) research on advanced displays
  - RSC (Behringer) research for streaming video for linking mobile and command center systems for detailed registration
  - Virginia Tech (Hix) evaluation of AR systems
- ONR research in digital urban reconstruction of terrain (DURT)
  - Berkeley (Malik): man-in-the loop DURT; reconstuction of lighting effects
  - MIT (Teller): ground-based, automated DURT
  - Georgia Tech (Ribarsky): DURT using plane/satellite imagery

Selected Publications

- *Mobile Augmented Reality: A Complex Human-Centered System*, S. Julier, S. Feiner and L. Rosenblum, In “Human-Centered Computing, Online Communities and VirtualEnvironments”, Springer Verlag, to appear, 2000.
- *Augmented Reality as an Example of a Demanding Human-Centered System*, S. Julier, S. Feiner and L. Rosenblum, *First EC/NSF Advanced Research Workshop*, 1-4 June 1999.
- Virtual and Augmented Reality 2020, L. Rosenblum, IEEE Computer Graphics and Applications, Vision 2000 Special Issue, Jan 2000, pp. 38--39.
- *Intelligent Filtering for Augmented Reality*, S. Sestito, S. Julier, M. Lanzagorta and L. Rosenblum, Proc. SimTecT 2000, Sydney, Australia, Feb 2000.
- *Information Filtering for Mobile Augmented Reality*, S. Julier, M. Lanzagorta, Y. Baillot, L. Rosenblum, S. Feiner, T. Höllerer, S. Setito, 2000 International Symposium on Augmented Reality, Munich, Germany, Oct 2000.

Contact Information

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